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Correspondence

Letter to the editor

Dear Professor Jamshidi:

It is a privilege to have an opportunity to express in writing my great admiration for Professor Zadeh's striking record of major research innovations, and my sincere appreciation for his important contributions to the development of my own career. However, I must first say that it is hard to believe we are already celebrating his 90th birthday, given the clarity, precision and vigor of his frequent postings on the BISC site.

It was indeed my good fortune that I came to the attention of Professor Zadeh soon after arriving from India to begin my graduate studies at MIT, in 1957. At the time, communication over rapidly fading multipath channels was a relatively new area of great interest. My Ph.D. advisor, Prof. Jack Wozencraft, was keenly aware of this from his consulting activities at the MIT Lincoln Laboratory, where Drs. Robert Price and Paul Green were developing the celebrated Rake receiver for such applications. Though the main ideas of Rake, which are receiving renewed attention in the remarkable resurgence of wireless communications, came from the theory developed in Price's 1953 MIT dissertation, there were still several issues that demanded further theoretical investigation. The presence of multiple paths meant that channel delay could be significant, and rapid fading led to significant bandwidth expansion. So, my advisor suggested a good first step would be to model such channels as linear time-variant systems. Of course, the name of Prof. Zadeh arose immediately, because in his 1949 Ph.D. thesis at Columbia, he had initiated the study of such systems by frequency-domain methods. His investigations were typically so complete it seemed, at first, that there was not much left to do. However, communication channels had the additional feature that they were effectively limited, both in duration and in bandwidth. This suggested the application of sampling theorems, and combining them with Prof. Zadeh's results led to the development of tapped-delay-line models for fading channels.

The next issue was how to identify the parameters of such models from input and output measurements. A sufficient condition for doing this was not hard, but checking that this condition was also necessary turned out to be quite frustrating. Just as I was about to give up, after several weeks of effort, a simple idea occurred to me: identification could only be possible if the sum of the degrees of freedom of the input and output signals was at least as great as the number of degrees of freedom of the channel. Carrying out this calculation led to a simple necessary and sufficient condition: the product of the channel duration and of the channel bandwidth should be less than unity.

This result came at a very opportune time, since Price and Green had noticed that there were various difficulties in communicating over channels where this condition was violated, which they now defined as "overspread" channels. Dr. Green brought my result to the attention of Prof. Zadeh, who by then was the acknowledged leading figure in the field of system theory. He, too, was pleasantly surprised by the result and its simple proof (only in retrospect, as he kindly put it, in one of his review papers), and invited me to present my work at a special session he was organizing at the annual convention of the Institute of Radio Engineers (IRE, now the IEEE) in New York, in 1959. For graduate students at the time, speaking at international conferences was indeed a privilege. So, it was with some trepidation that I went to introduce myself to the world-famous Professor Lotfi Zadeh. It was a great relief to see how gracious and warm he was in person, which helped me to make a successful presentation. He continued to follow my work, made generous comments about my results in his survey papers and talks, and also enabled my participation in several important international conferences. The visibility that his attention and efforts gave me was an invaluable early boost to my career.

In 1959 Prof. Zadeh was lured away from Columbia to UC Berkeley, a move that gave me even more opportunity to observe his continuing leadership in research, and to further benefit from his generosity. For example, on a recruiting visit to Stanford in 1962, I was not confident enough to rent a car to navigate the California freeways, so the famous professor drove down to pick me up from Stanford in order that I could give a seminar at Berkeley! Such actions, I am sure, contributed to my receiving a nice offer from Stanford.

At Berkeley, Prof. Zadeh continued to lead the way in new research directions. He recognized the importance of state-space descriptions of linear systems, and the relevance of automata theory to such studies, leading to the influential textbook with Desoer. He also saw the growing importance of the still young field of computer science to further progress in electrical engineering, and encouraged the recruitment of faculty with interests in that area; a notable example of such was Eugene Wong

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from IBM. Such leadership qualities led to Prof. Zadeh being named, in 1963, Chair of the department, where he had further scope to put forward his vision of the future of electrical engineering. A daring move was to rename the Electrical Engineering Department, the Electrical Engineering and Computer Science Department. Besides internal opposition from the EE department, he was faced with opposition from an already existing Computer Science Department at the College of Arts and Sciences. And no one outside Berkeley appreciated the significance of the move. Zadeh was undeterred, and his position was vindicated a few years later, when even the famous EE department at MIT renamed itself the EECS Department.

I had a ringside seat at some of these early developments during a sabbatical that I spent at Berkeley in the first half of 1963. I had only recently been married, and my wife, Sarah, was very new to the United States. Prof. Zadeh and his wife, Fay, took special steps to make us feel welcome, and we enjoyed several evenings at their home. I well remember, with Sarah leaving Berkeley a few months later to visit her parents in India, Prof. Zadeh calling her on the evening before her departure to wish her a safe journey. Such generosity was also extended to many of his colleagues at Berkeley and elsewhere.

While still Chair, Zadeh wrote his path-breaking paper on fuzzy systems. The rest is history, as the last 45 years have amply demonstrated. It is one of my several regrets that my interests had by then become so diverged that I never had the energy to follow this field. However, I have followed with pleasure several important further ideas, for example on linguistic variables and on computing with words to which Prof. Zadeh continues to contribute and has aptly called the field of Soft Computing. As his postings to the BISC site demonstrate, there seems to be no sign of his retiring from the frontiers of his many activities in research, or from his encouragement and support of younger colleagues, as almost all of us are by now!

For over 50 years, it has indeed been a remarkable privilege for me to have known Professor Lotfi Zadeh and his equally gracious, generous and accomplished wife, Fay. I wish both of them many more years of continued productive activity, health and happiness.

Thomas Kailath has been at Stanford University since 1963, where he is Hitachi America, Professor of Engineering, Emeritus.

His research has ranged over several fields of engineering and mathematics, including information theory, communications, linear systems, estimation and control, signal processing, semiconductor manufacturing, probability and statistics, matrix and operator theory. He has also co-founded and served as Director of several high-technology companies. These efforts have been aided by a stellar array of over a hundred doctoral and postdoctoral scholars.

Major honors awarded to Professor Kailath include the Shannon Award of the IEEE Information Theory Society; the Education and Signal Processing Medals of the IEEE, as well as its Medal of Honor; Guggenheim and Churchill Fellowships; honorary degrees from Sweden, Scotland, Spain, France, India and Israel; and election to the US National Academy of Engineering, the US National Academy of Sciences, the American Academy of Arts and Sciences, the Silicon Valley Engineering Hall of Fame, and Foreign Membership of the Royal Society of London, the Indian National Academy of Engineering, the Royal Spanish Academy and others. His latest major awards are Padma Bhushan, India's third highest civilian award, presented by the President of India; Foreign Membership of the Royal Society of London; the Blaise Pascal Medal of the European Academy of Sciences; and the BBVA Frontiers of Knowledge Award in Information and Communication Technologies.

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